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Description

The present invention relates generally to devices for conducting electrical current, for example, connectors, switches and sensors.

The invention is concerned, more especially, with current conducting devices for use in locations, for example in electrostatographic printing machines, where they may be exposed to contaminating substances.

In electrostatographic printing apparatus commonly used today a photoconductive insulating member is typically charged to a uniform potential and thereafter exposed to a light image of an original document to be reproduced. The exposure discharges the photoconductive insulating surface in exposed or background areas and creates an electrostatic latent image on the member which corresponds to the image contained within the original document. Alternatively, a light beam may be modulated and used to selectively discharge portions of the charged photoconductive surface to record the desired information thereon. Typically, such a system employs a laser beam. Subsequently, the electrostatic latent image on the photoconductive insulating surface is made visible by developing the image with developer powder referred to in the art as toner. Most development systems employ developer which comprises both charged carrier particles and charged toner particles which triboelectrically adhere to the carrier particles. During development the toner particles are attracted from the carrier particles by the charged pattern of the image areas of the photoconductive insulating area to form a powder image on the photoconductive area. This toner image may be subsequently transferred to a support surface such as copy paper to which it may be permanently affixed by heating or by the application of pressure.

In commercial applications of such products it is necessary to distribute power and/or logic signals to various sites within the machine. Traditionally, this has taken the form of utilizing conventional wires and wiring harnesses in each machine to distribute power and logic signals to the various functional elements in an automated machine. In such distribution systems, it is necessary to provide electrical connectors between the wires and components. In addition, it is necessary to provide sensors and switches, for example, to sense the location of copy sheets, documents, etc.. Similarly, other electrical devices such as interlocks, etc. are provided to enable or disable a function.

The most common devices performing these functions have traditionally relied on a metal-to-metal contact to provide a conductive path for conducting electric current from one location to another While this long time conventional approach has been very effective in many applications, it nevertheless suffers from several difficulties. For example, one or both of the metal contacts may be degraded over time by the formation of an insulating film due to oxidation of the metal. This film may not be capable of being pierced by the normal contact force by low energy (5 volts and 10 milliamps) power present in the other contact. This is complicated by the fact that according to Holm, Electric Contacts, *page 1*, 4th Edition, *1967*, published by Springer-Verlag, no amount of force even if the contacts are infinitely hard can force contact in more than three places. Corroded contacts can result in the creation of radio frequency interference (noise) which may disturb sensitive circuitry in the machine. In addition, the conventional metal to metal contacts are susceptible to contamination by dust and other debris in the machine environment. In an electrostatographic printing machine, for example, toner particles are generally airborne within the machine and may collect and deposit on one or more such contacts. Another common contaminant in a printing machine is a silicone oil which is commonly used as a fuser release agent. This contamination may also be sufficient to inhibit the necessary metal-to-metal contact. Accordingly, the direct metal-to-metal contact suffers from low reliability particularly in low energy situations. To improve the reliability of such contacts, particularly for low energy applications, contacts have been previously made from expensive rare earth elements such as gold, palladium, silver and rhodium or specially developed alloys such as palladium nickel and, in some applications, contacts have been placed in a vacuum or hermetically sealed. In addition, metal contacts can be self-destructive and will burn out since most metals have positive coefficient of thermal conductivity and as the contact gets hot it becomes less conducting thereby becoming hotter with the passage of additional current. Final failure may follow when the phenomenon of current crowding predominates the conduction of current. In addition to being unreliable as a result of being susceptible to contamination, traditional metal contacts and particularly sliding contacts are also susceptible to wear over long periods of time.

The following prior art is of interest on connection with the present invention:

U.S. Patent 4,347,287 to Lewis et al. describes a system for forming a segmented pultruded shape in which a continuous length of fiber reinforcements are impregnated with a resin matrix material and then formed into a continuous series of alternating rigid segments and flexible segments by curing the matrix material impregnating the rigid sections and removing the matrix material impregnating the flexible sections. The matrix material is a thermosetting resin and the fiber reinforcement may be glass, graphite, boron or aramid fibers.

U.S. Patent 4,569,786 to Deguchi discloses an electrically conductive thermoplastic resin composi-

tion containing metal and carbon fibers. The composition can be converted into a desired shaped product by inlection molding or extrusion molding (see col. 3, lines 30-52).

U.S. Patent 4,358,699 to Wilsdorf describes an electrical fiber brush and a method of making it wherein the electrical properties of the brush are controlled by the fiber wires by making extremely large number of fiber wires of very small diameters to contact the object at the working surface of the brush. Quantum-mechanical tunneling is expected to become the predominant mechanism of current conduction, providing extremely good brush performance while at the same time brush wear is very low.

U.S. Patent 4,641,949 to Wallace et al. describes a conductive brush paper position sensor wherein the brush fibers are conductive fibers made from polyacrylonitrile, each fiber acting as a separate electrical path through which the circuit is completed.

U.S. Patent 4,553,191 to Franks et al. describes a static eliminator device having a plurality of resilient flexible thin fibers having a resistivity of from about 2 x 10^3 ohms centimeters to 1 x 10^6 ohms centimeters. Preferably, the fibers are made of a partially carbonized polyacrylonitrile fiber.

U.S. Patent 4,369,423 to Holtzberg describes a composite automobile ignition cable which has an electrically conductive core comprising a plurality of mechanically and electrically continuous filaments such as graphitized polyacrylonitrile and electrically insulating elastomeric jacket which surrounds and envelopes the filaments.

U.S. Patent 4,761,709 to Ewing et al. describes a contact brush charging device having a plurality of resiliently flexible thin fibers having a resistivity of from about 10^2 ohms-cm to about 10^6 ohm-cm which are substantially resistivity stable to changes in relative humidity and temperature. Preferably the fibers are made of a partially carbonized polyacrylonitrile fiber.

Electric Contacts by Ragnar Holm, 4th Edition, published by Springer-Verlay, 1967, pages 1-53, 118-134, 228, 259 is a comprehensive description of the theory of electrical contacts, particularly metal contacts.

The present invention provides a device for conducting electric current comprising two contacting components at least one of which is a pultruded composite member comprising a plurality of small diameter conductive fibers embedded in a polymer matrix, the fibers being oriented in the matrix in the direction substantially parallel to the axial direction of the member and being continuous from one end of the member to the other to provide a plurality of potential electrical contacts at each end of the member. Typically the device is a switch, sensor or connector.

In a further aspect of the present invention, the conductive fibers are carbon fibers preferably carbonized polyacrylonitrile fibers.

In a further aspect of the present invention, the fibers are generally circular in cross section and have a diameter of from about 4 micrometers to about 50 micrometers and preferably from about 7 micrometers to about 10 micrometers.

In a further aspect of the present invention, the fibers have DC volume resistivity of from about 1 x 10^{-5} to about 1 x 10^{10} ohm cm and preferably from about 1 x 10^{-3} to about 10 ohm cm.

In a further aspects of the present invention, the fibers are present in the pultruded component in an amount of from about 5% to about 98 by weight, and preferably at least 50% by weight, and more especially about 90% by weight.

In a further aspects of the present invention, the.polymer matrix is a structural thermoplastic or thermosetting resin and is preferably a polyester or epoxy resin.

In a further principle aspect of the present invention, the pultruded member is a mechanical member as well as an electrical component.

In a further aspect of the present invention, both components are pultruded members and one or both of them function as mechanical member as well as an electrical component.

In a further aspect of the present invention, the pultruded member has at least one machine feature incorporated therein.

In a further aspect of the present invention, the polymer matrix is removed from one end of the pultruded member to expose the individual fibers.

In a further aspect of the present invention, the two components of the device are maintained in contact by a flexible fastener.

In a further aspect of the present invention, the polymer matrix can be a thermosetting elastomer.

A machine including a plurality of electrical components each requiring the supply of electrical current for proper functioning may include at least one electrical devices in accordance with the present invention.

By way of example, embodiments of the invention will be described with reference to the accompanying drawings in which:

Figure 1 is a representation in cross section of an electrostatographic printing machine.

Figure 2 illustrates in greater detail the document handler of Figure 1, which incorporates a device in accordance with the present invention.

Figure 3 is an enlarged sectional view illustrating a sensor used in the document handler of Figure 2.

Figure 4 illustrates an electrical connection between a pultruded member and a conductive fiber brush.

Figure 5 illustrates an electrical connection similar to that of Figure 4, wherein both contacts are pultruded members.

Figure 6 is an illustration in cross section of an

electrical connector in accordance with the invention.

Figure 7 illustrates an electrical connection between a pultruded member and electrical contacts.

Figure 8 illustrates a variety of representative cross sections for a pultruded member for use in e device in eccordance with the present invention.

Various current conducting devices are described below, a feature of eech device being that it incorporates en electrical contact component which is a composite member manufactured by a process known generelly as pultrusion. This process generally consists of pulling continuous lengths of fibers through a resin bath or impregnator and then into a preforming fixture where the section is partially sheped and excess resin end/or air are removed end then into heated dies where the section is cured continuously. Typically, the process is used to meke fiberglass reinforced plastic, pultruded shapes. For a detailed discussion of pultrusion technology, reference is directed to "Handbook of Pultrusion Technology" by Raymond W. Meyer, first published in 1985 by Chepman and Hall, New York.

To form the pultruded components of the devices as described below, conductive fibers are submersed in a polymer bath and drawn through a die opening of suitable shape et high tempereture to produce e solid piece, of the dimensions and shepe of the die, which can be cut, shaped and mechined. As a result, thousands of conductive fiber elements are contained within the polymer metrix, the ends of which fibers ere exposed at the cut surfaces to provide electrical contacts. This very large redundency and eveilability of electrical contacts enables a substantial improvement in the reliability of these contact components. Since the plurality of small diemeter conductive fibers are pulled through the polymer bath and heeted die as a continuous length, the shaped member is formed with the fibers being continuous from one end of the member to the other and oriented within the resin matrix in a direction substantially parallel to the axial direction of the member. By the term "axiel direction" it is intended to define a lengthwise or longitudinal direction along the major axis. Accordingly, the pultruded composite may be formed in a continuous length and cut to any suitable dimension providing at each end e very large number of potentiel electrical contacts at the ends of each of the individual fibers. As will become apparent hereinafter, these pultruded composite members may be used for either one or two of the contacting components in a device for conducting electric current.

Any suitable fiber may be used in the pultruded contact components. Typicelly, the conductive fibers will have a DC volume resistivity of from about 1 x 10^{-5} to about 1 x 10^{10} ohm cm and preferably from about 1 x $10^{-3}$to about 10 ohm cm to minimize resistance losses. However, higher resistivity materials mey be used if the input level of the electronic device is sufficiently high. In addition, the individual conductive fibers are generally circular in cross section and have a diameter generally in the order of from about 4 to about 50 micrometers and preferably from about 7 to 9 micrometers which provides a very high degree of redundancy in e small axial erea. The fibers ere typically flexible and compatible with the polymer systems. Typical fibers include cerbon, carbon/graphite, metallized or metal coeted carbon fibers and metal coated glass fibers.

Particulerly preferred fibers that may be used are those fibers that are obtained from the controlled heet treetment processing to yield partial carbonization of the polyecrylonitrile (PAN) precursor fibers. It has been found for such fibers thet, by carefully controlling the temperature of carbonization within certain limits, precise electrical resistivities for the carbonized carbon fibers may be obtained. The polyacrylonitrile precursor fibers are commercielly produced by the Stackpole Company, Celion Cerbon Fibers, Inc., division of BASF and others in yern handles of 1,000 to 160,000 filaments. The yern bundles are partially carbonized in a two-stage process involving stabilizing the PAN fibers at temperatures of the order of 300°C in an oxygen atmosphere to produce preoxstabilized PAN fibers followed by carbonization at elevated temperatures in an inert (nitrogen) atmosphere. The D.C. electrical resistivity of the resulting fibers is controlled by the selection of the temperature of carbonization. For example, carbon fibers having an electrical resistivity of from about 10^2 to about 10^6 ohms-cm are obteined if the carbonization temperature is controlled in the range of from about 500°C to 750°C. For further reference to the processes that may be employed in making these carbonized fibers attention is directed the above-referenced U.S. Patent 4,761,709 to Ewing et al. and the literature sources cited therein at column 8. Typically these carbon fibers have a modulus of from about 30 million to 60 million psi or 205 - 411 GPa which is higher than most steels thereby enabling e very strong pultruded composite member. The high temperature conversion of the polyacrylonitrile fibers results in a fiber which is about 99.99% elemental carbon which is inert and which when used in e high energy application upon oxidetion will yield only carbon monoxide or carbon dioxide which ere gases thet do not contaminate the fiber end contacts.

One of the advantages of using conductive carbon fibers is thet they have a negative coefficient of thermal conductivity so that as the individual fibers become hotter, they become more conductive. This provides an advantage over metal fibers since the metal fibers operate in just the opposite manner and therefore tend to burn out by self destructing. In a particular application, where very high conductivity of the order of 105 (ohm cm)$^{-1}$ is desired, the fibers may be metallized or plated with a metal such as nickel, sil-

ver or gold. The carbon fibers have a further advantage in that their surfaces are inherently rough thereby providing better adhesion to the polymer matrix.

Any suitable polymer matrix may be employed for producing the pultruded contact components. The polymer may be insulating or conducting. If optimum electrical conduction is desired at the edges of the pultrusion a conducting polymer may be used. Conversely, if insulating properties are desired at the edges of the pultrusion an insulating polymer may be used.

Typically, the polymer is selected from the group of structural thermoplastic and thermosetting resins. Polyester, epoxy and vinyl esters are in general, suitable materials with the polyester being preferred due to its short cure time and relative chemical inertness. If an elastomeric matrix is desired, a silicone, fluorosilicone or polyurethane elastomer may provide the polymer matrix. Typical specific materials include Hetron 613, Arpol 7030 and 7362 available from Oshland Oil, Inc., Dion Iso 6315 available from Koppers Company, Inc. and Silmar 5-7956 available from Vestron Corporation. For additional information on suitable resins attention is directed to Chapter 4 of the above-referenced Handbook by Meyer. Other materials may be added to the polymer bath to provide properties such as corrosion or flame resistance as desired. In addition, the polymer bath may contain fillers such as calcium carbonate, alumina, silica or pigments to provide a certain color or lubricants to reduce friction, for example, in sliding contacts. Further additives to alter the viscosity, surface tension or to assist in bonding the pultrusion to the other materials may be added. Naturally, if the fiber has a sizing applied to it, a compatible polymer should be selected. For example, if an epoxy resin is being used, it would be appropriate to add an epoxy sizing to the fiber to promote adhesion.

The fiber loading in the polymer matrix depends upon the conductivity desired and the cross sectional area. Typically, the resins have a specific gravity of from about 1.1 to about 1.5 while the fibers have a specific gravity of from about 1.7 to about 2.5. In providing the levels of conductivity heretofore mentioned, typically the pultruded composite member is more than 50% by weight fiber and preferably more than 80 or even 90% fiber, the higher fiber loadings providing more fibers for contacts and lower bulk resistivity. To increase the conductivity of the matrix additional conductive fiber may be added.

The pultruded composite members may be prepared according to the pultrusion technique as described, for example, by Meyer in "Handbook of Pultrusion Technology". In general, this will involve the steps of pre-rinsing the continuous multi-filament strand of conductive carbon fibers in a pre-rinse bath followed by pulling the continuous strand through the molten or liquid polymer followed by pulling it through a heated die which may be at the curing temperature of the resin into an oven dryer, if such is necessary, and then to a cut-off or take-up position. For further and more complete details of the process attention is directed to Meyer. While the desired final shape of the pultruded composite member may be that provided by the die, alternatively it is capable of being machined with conventional carbide tools. Typically, holes, slots, ridges, grooves, convex or concave contact areas or screw threads may be formed in the pultruded composite member by conventional machining techniques. Attention is directed to Figure 8 of the accompanying drawings wherein a variety of die configurations are illustrated which may be used to produce the corresponding pultruded cross sectional shapes. While the individual dots representing the individual fibers are depicted in an orderly pattern, it will be understood that they more generally appear in a random pattern.

Typically, the fibers are supplied as continuous filament yarns having, for example, 1, 3, 6, 12 or up to 160 thousand filaments per yarn and provide in the formed pultruded member from about 1×10^5 to about 2.5×10^6 contacts per cm^2.

A pultruded member so formed may be used to provide at least one of the contacting components in a device for conducting electrical current. In addition or alternatively both of the contacts may be made from similar or dissimilar pultruded composite members. Furthermore, one or both of the contacts may provide a mechanical or structural function. For example, in addition to performing as a conductor of current for a connector a pultruded member may also function as a guide pin. A pultruded member may act as a rail for a scanning head to ride on and also provide a ground return path.

Attention is directed to Figures 3 through 7 in the drawings for the following description of devices incorporating pultruded contact components manufactured as described above, and to Figures 1 and 2 for the description of a printing/ reproduction machine incorporating the device of Figure 3.

With reference to Figure 1, there is shown an electrophotographic printing or reproduction machine employing a belt 10 having a photoconductive surface. Belt 10 moves in the direction of arrow 12 to advance successive portions of the photoconductive surface through various processing stations, starting with a charging station including a corona generating device 14. The corona generating device charges the photoconductive surface to a relatively high substantially uniform potential.

The charged portion of the photoconductive surface is then advanced through an imaging station. At the imaging station, a document handling unit 15 positions an original document 16 facedown over exposure system 17. The exposure system 17 includes lamp 20 illuminating the document 16 positioned on

transparent platen 18. The light rays reflected from document 16 are transmitted through lens 22 which focuses the light image of original document 16 onto the charged portion of the photoconductive surface of belt 10 to selectively dissipate the charge. This records an electrostatic latent image on the photoconductive surface corresponding to the information areas contained within the original document.

Platen 18 is mounted movably and arranged to move in the direction of arrows 24 to adjust the magnification of the original document being reproduced. Lens 22 moves in synchronism therewith so as to focus the light image of original document 16 onto the charged portion of the photoconductive surface of belt 10.

Document handling unit 15 sequentially feeds documents from a holding tray, seriatim, to platen 18. The document handling unit recirculates documents back to the stack supported on the tray. Thereafter, belt 10 advances the electrostatic latent image recorded on the photoconductive surface to a development station.

At the development station a pair of magnetic brush developer rollers 26 and 28 advance a developer material into contact with the electrostatic latent image. The latent image attracts toner particles from the carrier granules of the developer material to form a toner powder image on the photoconductive surface of belt 10.

After the electrostatic latent image recorded on the photoconductive surface of belt 10 is developed, belt 10 advances the toner powder image to the transfer station. At the transfer station a copy sheet is moved into contact with the toner powder image. The transfer station includes a corona generating device 30 which sprays ions onto the backside of the copy sheet. This attracts the toner powder image from the photoconductive surface of belt 10 to the sheet.

The copy sheets are fed from a selected one of trays 34 and 36 to the transfer station. After transfer, conveyor 32 advances the sheet to a fusing station. The fusing station includes a fuser assembly for permanently affixing the transferred powder image to the copy sheet. Preferably, fuser assembly 40 includes a heated fuser roller 42 and a backup roller 44 with the powder image contacting fuser roller 42.

After fusing, conveyor 46 transports the sheets to gate 48 which functions as an inverter selector. Depending upon the position of gate 48, the copy sheets will either be deflected into a sheet inverter 50 or bypass sheet inverter 50 and be fed directly onto a second gate 52. Decision gate 52 deflects the sheet directly into an output tray 54 or deflects the sheet into a transport path which carries them on without inversion to a third gate 56. Gate 56 either passes the sheets directly on without inversion into the output path of the copier, or deflects the sheets into a duplex inverter roll transport 58. Inverting transport 58 inverts and stacks the sheets to be duplexed in a duplex tray 60. Duplex tray 60 provides intermediate or buffer storage for those sheets which have been printed on one side for printing on the opposite side.

With reference to Figure 2, there is shown the path 62 of movement of a document 16 driven by pinch rolls 64 through document size sensor array 66 onto platen 18. The document size sensor array 66 generally includes an array of oppositely disposed conductive contacts. One such pair is illustrated as fiber brush 68 carried in upper support 70 in electrical contact with pultruded composite member 72 as illustrated in greater detail in Figure 3 carried in lower conductive support 74. The pultruded composite member comprises a plurality of conductive fibers 71 in a polymer matrix 75 having a surface 73 at which the ends of the fibers are available for contact with the fibers of the brush 68 which is mounted transversely to the sheet path to contact and be deflected by passage of a document between the contacts. When no document is present, the brush fibers form a closed electrical circuit with the surface 73 of the pultruded member 72. It should be noted that single position sensors can also be used. With reference to the pultruded members illustrated in Figures 2 and 3 as previously discussed, it will be appreciated that the fiber loading of the member is typically much greater than illustrated.

A test was conducted of the device illustrated in Figure 3 wherein fiber brush 68 was made of Celion C-6000 a polyacrylonitrile fiber available from Celion Carbon Fibers, Inc., a division of BASF, Charlotte, North Carolina with 6000 fibers per yarn. The fibers have a 0.7% by weight sizing of polyvinylpyrolidone, a resistivity of 10^{-3} ohm-cm and are 7 to 10 micrometers in diameter. The brush was formed by encasing one end of the fibers in an ultrasonically welded conductive plastic holder and the other contact 72 was a pultruded pellet having a circular cross section about 6 mm in diameter cut to a length of about 3mm. The pultruded pellet was formed from carbon fibers 7 to 10 micrometers in diameterhaving a resistivity of about 10^{-3} ohm cm in a polyester matrix of which 30% to 50% by weight was fiber. The pellet is available from Diversfied Fabricators, Incl., Winona, Minn..

The pellet was attached to the conductive support 74 using a silver filled conductive epoxy and the switch as formed was connected to DC power supply 5 volts by current sensing resistor which allows 10 milliamps that flow through the contact. In a test fixture, the sensor was actuated for a hundred million actuations with no failures. A similar test was conducted except that the pultruded contact was replaced with a metal contact. When placed in the test fixture, failure was experienced after about one hundred thousand actuations as a result of an oxide buildup on the metal contact and relatively low force on the brush being insufficient at such low energy lev-

els to pierce thecontaminant layer.

Additional tests were conducted for the device illustrated in Figure 3 where the pultruded member had been immersed in fuser oil, water or had toner spilled on it. In each instance, it was demonstrated that effective switching was achieved even under such high level of contact discrimination.

Attention is directed to Figure 4 wherein an alternative form of the Figure 3 device is illustrated. More specifically, the pultruded composite member 78 has been machined to provide a rounded groove 80 therein to provide contact with the fibers of a brush contact 86. In Figure 5, a similar device comprises at the contact interface two pultruded members 82 and 84 both of which have been slightly machined to assure good contact. In one member a rounded groove 83 has been provided and in the other member the end thereof has been rounded at 85 to mate with the groove.

With reference to Figure 6, a device including two pultruded composite members forming a connector is illustrated. Each of the pultruded members 87, 88 is connected to an electrical wire 90 and 91, respectively, through a hole in the end of the pultruded member and is contained in a molded plastic end cap 92, 93 in a housing 95, 96. The connector is designed as a male and female compatible unit which is held together by flexible fastener material such as Velcro a trademark of Velcro Company or Scotch Flexlock 97 a trademark of 3M. Naturally, the pultruded composite members 87,88 may be joined in electrical contact with the wires 90,91 by any well known technique such as crimping, inserting the electrical lead or wire through a drilled hole in the pultruded member, soldering or adhesively securing it,etc..

Figure 7 illustrates an elastomeric pultruded member 98 biased into electrical contact at each end 100, 101 with contacts 102, 103 by a force exerted near near the fulcrum center.

While the use of a pultruded member as an electrical contact component in particular devices has been illustrated, it will be understood that it has utility in other applications including high energy applications. For example, a pultruded contact member as described can be used in audio and signal level connections, non-metallic busses, corotron array connections, grounding or biasing elements, supply outputs, etc. If a brush-type contact is desired on the end of a pultruded composite member, this may be achieved merely by removing the polymer matrix from the composite member by solvent removal or by burning or etching the binder away.

Through the use of pultruded contact components as described above, extremely reliable electrical devices such as sensors, switches, connectors, interlocks, etc. can be provided. This reliability is achieved because the composite pultruded members provide such an enormously large number of potential electrical contacts that the electrical redundancy is orders of magnitude greater than for conventional metal-to-metal contact. Furthermore, the contact does not degrade by oxidation over time, and its integrity remains intact even when it is contaminated. The pultruded contact component is relatively low in cost, and easily manufacturable into a variety of cross sectional shapes and can be used to provide both a structural and mechanical function. It provides a high contact reliability at a relatively low cost. It is capable of functioning for very extended periods of time in low energy configurations, and is also capable of functioning in a high voltage system, for example, in conjunction with the composite automobile ignition cable described in U.S. Patent No. 4,369,423 to Holtberg. Such a system will be free of electromagnetic interference or radio frequency interference since the carbon wire in the contact would tend to dissipate any transient currents in the wire before any interference is generated which would otherwise interfere with the logic. In addition, when compared to metal-to-metal contacts, the pultruded composite members experience low internal stress on heating and cooling since they have a lower linear coefficient of thermal expansion.

The disclosures of the patents and the other references including the Meyer book and Holm book referred to herein are hereby specifically and totally incorporated herein by reference.

Although the Figure 3 device has been generally illustrated above for use in electrostatographic printing apparatus, it will be appreciated that it has equal application to a larger array of machines with electrical components, as have other devices in accordance with the invention.

Claims

1. An electrical device comprising two electrical contact components (68,72) engagable one with another, at least one of said components being a pultruded composite member comprising a plurality of conductive fibers (71) embedded in a polymer matrix (75) said plurality of fibers being oriented in said matrix in a direction substantially parallel to the axial direction of said member and being continuous from one end of said member to the other to provide a plurality of potential electrical contacts at each end of said member.

2. A device as claimed in claim 1, wherein said conductive fibers are carbon fibers.

3. A device as claimed in claim 1 or claim 2, wherein the fibers are generally circular in cross section and have a diameter of from about 4 micrometers to about 50 micrometers.

4. A device as claimed in any one of the prededing claims, wherein the fibers have a DC volume resistivity of from about 1 x 10^{-5} ohm cm to about 1 x 10^{10} ohm cm.

5. A device as claimed in any one of the preceding claims, wherein the composite member comprises at least 5 % by weight fibers.

6. A device as claimed in any one of the preceding claims, wherein said polymer matrix is a structural thermoplastic or thermosetting resin.

7. A device as claimed in any one of the claims 1 to 5, wherein said polymer matrix is a crosslinked silicone elastomer.

8. A device as claimed in any one of the preceding claims, wherein both of said electrical contact components are pultruded composite members.

9. A device as claimed in any one of the preceding claims, wherein the/each pultruded member is a structural member as well as an electrical contact component.

10. A device as claimed in claim 2, wherein said carbon fibers have a metal coating thereon.

11. A device as claimed in any one of the preceding claims, wherein the polymer matrix is removed from one end of said pultruded member to expose the individual fibers.

12. A device as claimed in any one of the preceding claims, wherein said two contact components are maintained in engagement with one another by a flexible fastener.

13. A device as claimed in any one of the prceding claims, the device being an electrical switch, sensor or connector

Patentansprüche

1. Eine elektrische Einrichtung umfassend zwei elektrische Kontaktteile (68, 72), die miteinander in Eingriff bringbar sind, und wobei wenigstens eines der genannten Teile ein ziehstranggepreßtes Verbundelement ist, das eine Mehrzahl von leitenden Fasern (71) in eine Polymermatrix (75) eingebettet umfaßt, wobei die genannte Mehrzahl von Fasern in der genannten Matrix in einer Richtung im wesentlichen parallel zu der axialen Richtung des genannten Elementes ausgerichtet sind und von einem Ende des genannten Elementes zu dem anderen Ende durchgehend sind, um eine Mehrzahl von möglichen, elektrischen Kontakten an jedem Ende des genannten Elementes bereitzustellen.

2. Eine Einrichtung wie in Anspruch 1 beansprucht, in der die genannten leitenden Fasern Kohlenstoffasern sind.

3. Eine Einrichtung, wie in Anspruch 1 oder Anspruch 2 beansprucht, in der die Fasern einen allgemein kreisförmigen Querschnitt aufweisen und einen Durchmesser von ungefähr 4 Mikrometer bis 50 Mikrometer haben.

4. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der die Fasern einen spezifischen Gleichstromvolumenwiderstand von ungefähr 1 x 10^{-5} Ohm · cm bis ungefähr 1 x 10^{10} Ohm · cm haben.

5. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der das Verbundelement wenigstens 5 Gew.-% Fasern umfaßt.

6. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der die genannte Polymermatrix ein struktureller, thermoplastischer oder wärmehärtender Kunststoff ist.

7. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche 1 bis 5 beansprucht, in der die genannte Polymermatrix ein vernetztes Silikonelastomer ist.

8. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der beide der genannten elektrischen Kontaktteile ziehstranggepreßte Verbundelemente sind.

9. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der das/jedes ziehstranggepreßte Element ein strukturelles bzw. konstruktives Element sowie ein elektrisches Kontaktteil ist.

10. Eine Einrichtung, wie in Anspruch 2 beansprucht, in die genannten Kohlenstoffasern auf sich eine Metallbeschichtung haben.

11. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der die Polymermatrix von einem Ende des genannten zieh-stranggepreßten Elementes entfernt ist, um die einzelnen Fasern freizulegen.

12. Eine Einrichtung, wie in irgendeinem der vorhergehenden Ansprüche beansprucht, in der die ge-

nannten zwei Kontaktteile durch ein flexibles Befestigungsmittel miteinander in Eingriff gehalten sind.

13. Eine Einrichtung, wie in irgendeinem der vorhergehen den Ansprüche beansprucht ist, wobei die Einrichtung ein elektrischer Schalter, ein Sensor oder ein Stecker ist.

Revendications

1. Dispositif électrique comprenant deux composants de contact électrique (68, 72) pouvant être engagés l'un dans l'autre, au moins l'un desdits composants étant un élément composite pultrudé comprenant une multitude de fibres conductrices (71) encastrées dans une matrice de polymère (75), ladite multitude de fibres étant orientée dans ladite matrice dans une direction pratiquement parallèle au sens axial dudit élément et étant continue entre une extrémité dudit élément et son autre extrémité afin de fournir une multitude de contacts électriques potentiels à chaque extrémité dudit élément.

2. Dispositif selon la revendication 1, dans lequel lesdites fibres conductrices sont des fibres de carbone.

3. Dispositif selon la revendication 1 ou la revendication 2, dans lequel les fibres ont une section transversale généralement circulaire et ont un diamètre compris entre environ 4 micromètres et environ 50 micromètres.

4. Dispositif selon l'une quelconque des revendications précédentes, dans lequel les fibres ont une résistance volumique en courant continu comprise entre environ 1×10^{-5} ohm-cm et environ 1×10^{10} ohms-cm.

5. Dispositif selon l'une quelconque des revendications précédentes, dans lequel l'élément composite comprend au moins 5 % en poids de fibres.

6. Dispositif selon l'une quelconque des revendications précédentes, dans lequel ladite matrice de polymère est une résine thermoplastique ou thermodurcissable structurale.

7. Dispositif selon l'une quelconque des revendications 1 à 5, dans lequel ladite matrice de polymère est un élastomère de silicone réticulé.

8. Dispositif selon l'une quelconque des revendications précédentes, dans lequel lesdits deux composants de contact électrique sont des éléments composites pultrudés.

9. Dispositif selon l'une quelconque des revendications précédentes, dans lequel le/chaque élément pultrudé est un élément structural ainsi qu'un composant de contact électrique.

10. Dispositif selon la revendication 2, dans lequel lesdites fibres de carbone ont sur leur dessus un revêtement métallique.

11. Dispositif selon l'une quelconque des revendications précédentes, dans lequel la matrice de polymère est enlevée à une extrémité dudit élément pultrudé de manière à mettre à nu les fibres individuelles.

12. Dispositif selon l'une quelconque des revendications précédentes, dans lequel lesdits deux composants de contact sont maintenus en engagement l'un dans l'autre par une attache flexible.

13. Dispositif selon l'une quelconque des revendications précédentes, le dispositif étant un commutateur électrique, un capteur ou un connecteur.

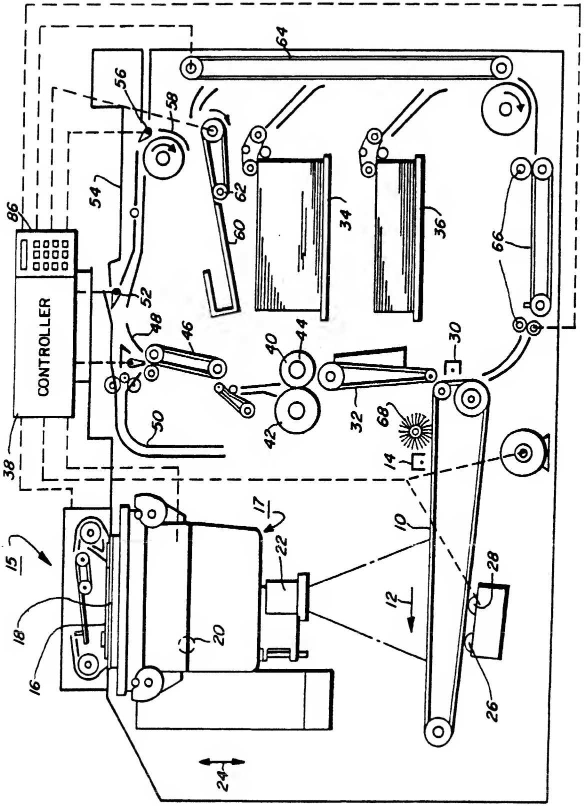
CONTROLLER
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FIG. 1

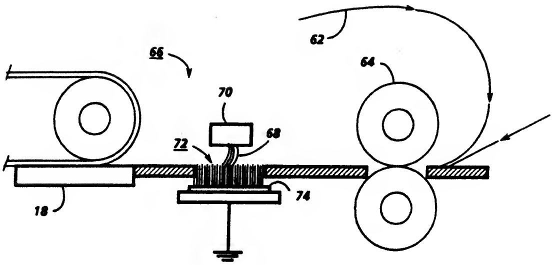

FIG. 2

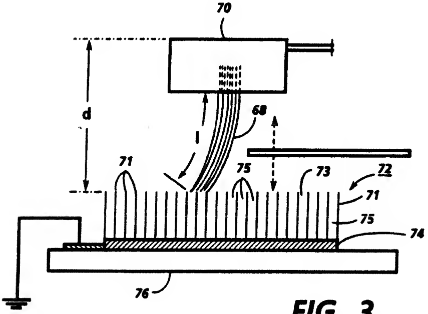

FIG. 3

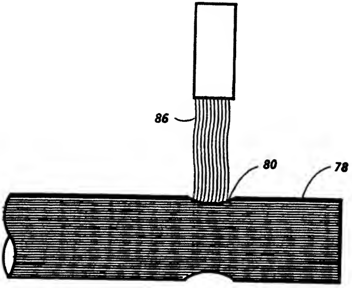

FIG. 4

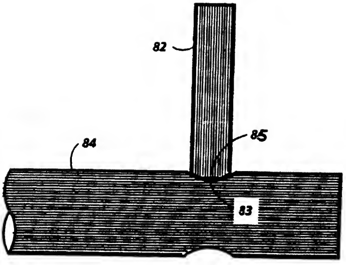

FIG. 5

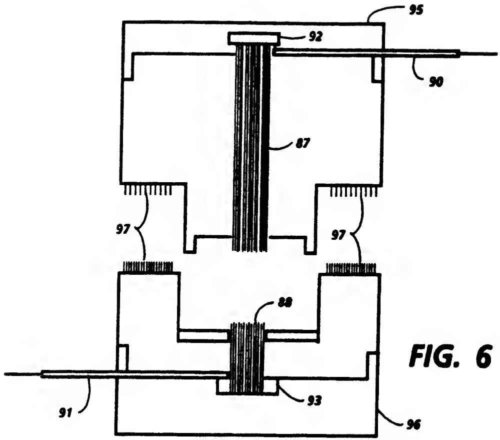

FIG. 6

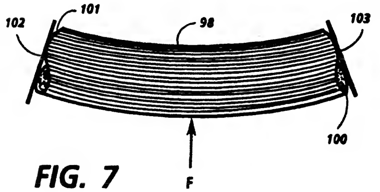

FIG. 7

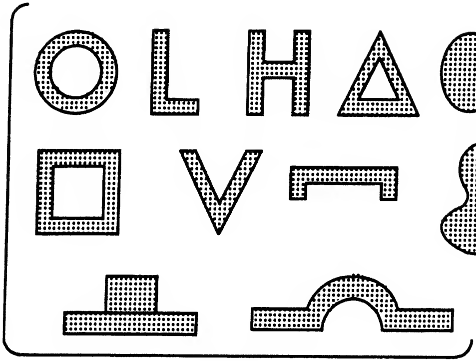

FIG. 8